FINAL REPORT OF CONTRACT NONR-2866 INCLUDING A HISTORY OF THE CONTRACT AND A BIBLIOGRAPHY OF SCIENTIFIC CONTRIBUTIONS SUPPORTED BY THE CONTRACT AT THE WOODS HOLE OCEANOGRAPHIC INSTITUTION FROM MARCH 1, 1959 TO JUNE 30, 1969

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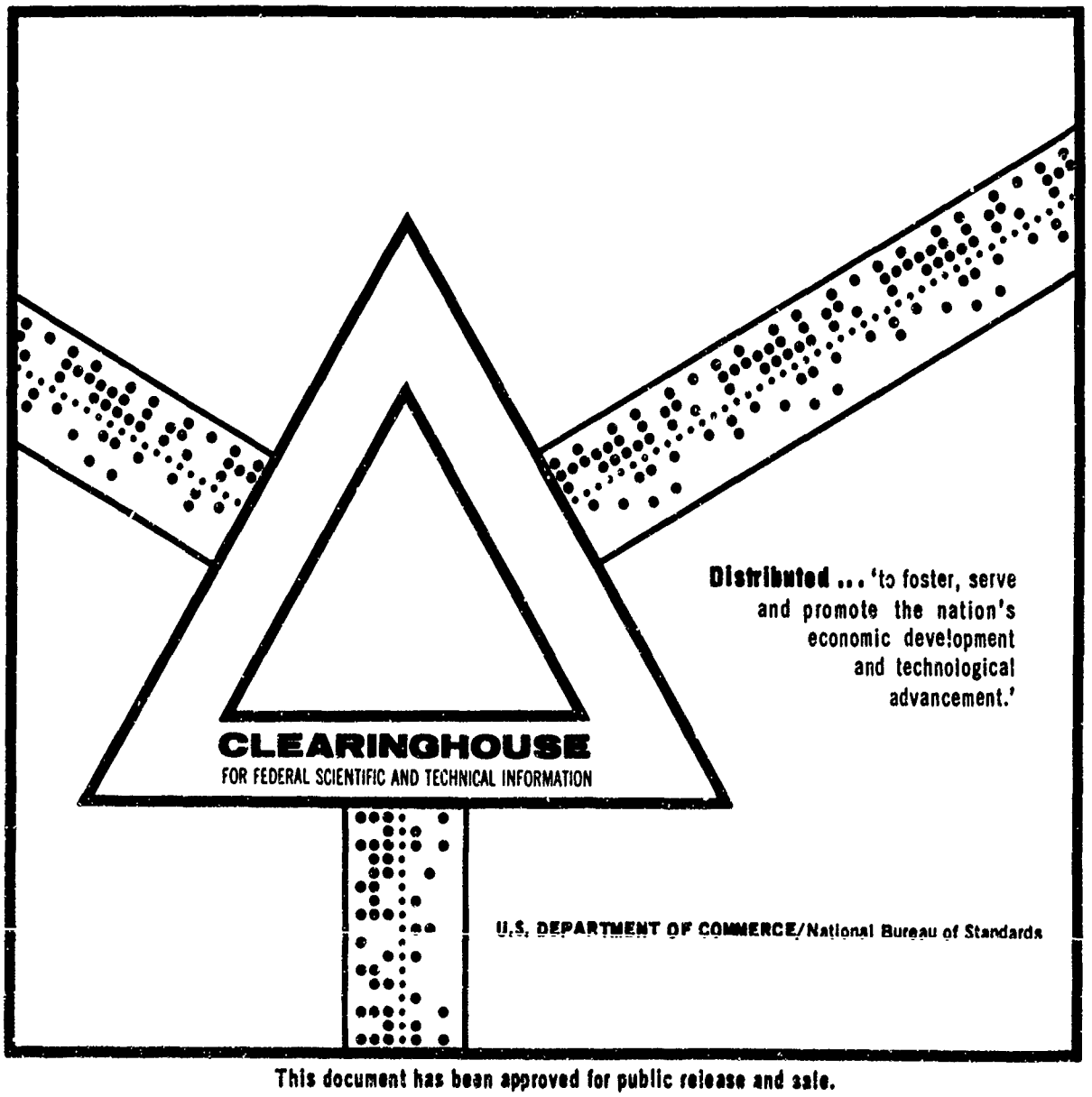
June 1969



WOODS HOLE OCEANOGRAPHIC INSTITUTION
Woods Hole, Massachusetts

REFERENCE NO. 69-51

Final Report of Contract Nonr-2866 including a History of the Contract and a Bibliography of Scientific Contributions Supported by the Contract at the Woods Hole Oceanographic Institution from March 1, 1959 to June 30, 1969.

by

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June 1969

TECHNICAL REPORT

Submitted to the Office of Naval Research as the FINAL REPORT under Contract Nonr-2866(00) NR 287-004.

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Approved for Distribution J. R. Heirtzler

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ABSTRACT

This is the final report of Contract Nonr-2866(00) including a history of the contract and a bibliography of scientific contributions supported by the contract at the Woods Hole Oceanographic Institution from March 1, 1959 to June 30, 1969. The contract was initiated as a project to provide basic environmental measurements in a broad ocean area between Bermuda and the Antilles that would limit the specifications and the performance of a large long range underwater acoustics system known as Project ARTEMIS. From the beginning in late 1958 until the present the research program included sound transmission studies, temperature and sound velocity measurements, studies of currents in the deep ocean and studies of the bottom conditions. This program of research has brought about better understanding of the ocean movements and reflecting properties of the ocean bottom in the Bermuda-Antilles area. A reliable environmental ocean measuring system was developed under this contract and put to use to determine spatial and temporal variations in the acoustic structure in the ocean.

INTRODUCTION

The Geophysics Department at the Woods Hole Oceanographic Institution has been responsible for a portion of the environmental research in the ocean in support of Project ARTEMIS under Contract Nonr-2866(00) since the contract was initiated late in 1958. This report will be a final report of the research into the ocean environmental factors that influence underwater acoustic propagation and pertinent to the needs in the development of an advanced acoustics system. As such it will contain a brief history of the research work and a bibliography.

Late in 1958, when Project ARTEMIS began, it was recognized that such a large scale feasibility study would require the cooperation of some twenty laboratories, frequent coordinating, planning and review conferences, and a major research effort to uncover the environmental factors that would limit the specifications and performance of the system. The research area in the ocean chosen for this large scale feasibility study was situated between Bermuda and the Antilles. J. B. Hersey, who was the principal investigator, in the Department of Geophysics for the Office of Naval Research contract with the Woods Hole Oceanographic Institution, set forth four categories that required an extensive research effort. These were: sound transmission studies, water structure studies, water current studies, and studies of bottom conditions. It was the considerable experience in the basic factors about the sound transmission medium and its boundaries that affect long range sound transmission, gained by the research efforts of the Geophysics Department of this Institution since 1953 and before, that helped immeasurably in the delineation of the important areas of research needed. Although there was a goodly amount of scientific knowledge available about the areas mentioned above, as well as specialty fields such as signal processing and the design of large sound transducers, the scale of the ARTEMIS feasibility study required

a considerable extrapolation of the state of the knowledge at that time. For instance, there was a great deal known about environmental variations in the sea but a considerable lack of the detailed knowledge required to make a prediction about the limitations of the system concept. We now recognize more fully the serious limitations placed on the performance of the ARTEMIS system, as initially conceived, by fluctuations in the ocean and by sound transmission loss and scattering due to bottom reflections. Indeed, the scale of the research effort into environmental factors undertaken has only recently provided a grasp of the complexity of ocean processes. The enormity of the ocean's environmental problem in long range underwater sound transmission, particularly when one is pushing to get the very most from an advanced systems development program, is beginning to be appreciated. Even to this day, questions such as how large one can make an underwater hydrophone array and achieve considerable gain cannot be answered simply. An answer to such a question requires measurements of the spatial and temporal coherence of acoustic signals in the ocean, the reflecting properties of the ocean floor and the sublayers below, and measurements of the noise distribution. All of these factors vary with location in the ocean. It is interesting, in retrospect, that the basic limitations of the ARTEMIS system were foreseen to be environmental in character and that a program of research into all of the above areas was carried out.

In the early years of this program extensive expeditions were undertaken to obtain pertinent information regarding sound transmission characteristics. Particularly, information was vital with respect to sound transmission loss on a year round basis. Therefore, measurements of transmission loss were conducted in the winter, as well as in the spring, summer, and fall. This kind of information was essential in considerations of the level of the source design and the amount of signal processing that would be required under the system's concept. There are a number of reports describing this research contained in the bibliography. Moreover, extensive studies of the bottom of the ocean, detailed site surveys, bottom photography, seismic studies of reflectors underneath the bottom

which could produce destructive as well as constructive interference in the frequency ranges of interest were all part of the systematic investigation of the ARTEMIS area carried out by the Department of Geophysics. Considerable effort went into the identification of sound paths and some of these sound paths have been given extensive study with regard to wavefront fluctuations by the research group of the Bell Telephone Laboratories and the scientists of Hudson Laboratories in efforts to optimize beamforming.

The sound velocity structure in the region was studied extensively by the Geophysics Department. Members of this department were the first to employ the National Bureau of Standards sound velocimeter to the ocean environment problem in the ARTEMIS area. The environmental system used for this work from the Institution's research ships has undergone development throughout the contract periods even up to this present time. Some brief description of the present capabilities that have resulted from this development program will be mentioned later. Both acoustic and oceanographic cruises were carried out by the Geophysics Department in an effort to identify reliable sound paths. Water structures near the surface were studied with the thermistor chain on long traverses of the ARTEMIS area in 1961 in order to determine the scale of the fluctuations and to determine the likelihood of multiple bottom reflections as opposed to sound channel and surface reflected type transmission. Thermistor chain observations gave considerable insight into the character of the ocean's fluctuations in the vicinity of the sea surface and it became obvious from these records that there were many scales of inhomogeneities affecting sound transmission. Any examination of these records at such an early date gave the impression that the internal motions of the ocean were overwhelmingly complex. It was clear from these research efforts that many years of study of this complex phenomenon of internal ocean movements would be required before a meaningful grasp of the processes involved could be established. Moreover, the very complexity of the records and the lack of adequate theories of turbulence precluded the possibility of any direct approach using the measurements in the prediction of acoustical fluctuations.

Indeed, even to this present day, although some real progress has been made, there is a real problem in trying to correlate oceanographic fluctuations and acoustical transmission fluctuations.

In the early and middle years of the contract period very little was known about deep currents in the ocean. Swallow float measurements were just beginning to be made and members of the Geophysics Department conducted drogue measurements to obtain estimates of the current flow with some emphasis on the vicinity of the proposed receiver array location. Transient currents were observed in the very deep ocean and there was concern as to how ocean currents might affect the lifetime of undersea equipment. There are several reports which describe efforts to obtain information about deep ocean currents. The difficulties of measuring ocean currents and of interpreting the results of such measurements is now well appreciated by oceanographers. The need for continued research into deep ocean currents is more fully appreciated. The lifetime and the complexity of the in-water ARTEMIS system has demonstrated that careful planning and design with enough thought to the ocean problems in the vicinity can provide a reasonably long life. However, many of the engineering problems associated with long life underwater installations have not been solved.

In the middle 60's extensive oceanographic cruises were taken by the Geophysics Department to make systematic measurements of sound velocity, temperature, salinity, and other variables in the ocean. The scale of these cruises over the ARTEMIS area was enlarged whenever the research could be sponsored jointly by other contracts held by the Institution.* After the realization that small scale internal wave fluctuations, known to have an important effect on sound transmission, could not be understood adequately without a study of large scale phenomena, the research

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* Progress reports of some of the work on this contract were issued periodically in WHOI reports in view of their pertinence to another contract, Nonr-4029(00). These brief accounts are cited in the bibliography in the semi-annual reports of Oceanographic and Underwater Acoustic Research.

program entered into a study of large scale Rossby waves. A major cruise of ATLANTIS II-22 in June 1966 was undertaken to learn about the ocean area and to study the thermal front region which passed through the area from west to east and may extend as far east as the mid-Atlantic ridge. Several reports on this work have been completed. They reveal that the Sargasso Sea is a very complicated region of eddies of different sizes and intensities which vary with depth. It is likely that the movement of these eddies have an influence on the smaller scale internal gravity waves and on acoustical fading phenomena.

During this period the Sylvania Applied Research Laboratory in Waltham, Massachusetts offered considerable assistance to the Institution in the development of an on-line sound velocity profiling system. A report on this work prepared by them is cited in the bibliography. During this period the Institution entered in closer cooperation with acoustical studies in progress by the Bell Telephone Laboratories. Many sound velocity profiles were obtained by the Institution's cruises to the area along sound transmission bearings from Argus Island, off Bermuda. These studies showed that thermal characteristics that occur near the ocean surface, particularly in the thermal front region, extend very deep into the ocean. Some ray computations were undertaken in order to study the influence of this thermal front region on sound transmission.

The purpose of CHAIN Cruise 67 was to study the thermal front region and to supply environmental measurements necessary to assist in the interpretation of acoustical studies. The acoustical measurements were carried out by the Bell Telephone Laboratories group under the guidance of Howard Broek. The results of this effort to relate environmental variations directly to acoustical fluctuations indicated some correlation with the longer scale ocean movements. However, it is clear that environmental measurements along a transmission run need to be obtained with relatively permanent installations in the water in addition to ocean measurements from ships.

An evaluation of the final sound velocity profiling system that was developed during this contract occurred on CHAIN Cruise 89 which took place during March and April of this year. This system plotted in final form during the cruise many of the sound velocity profiles , temperature,and other variables measured. The in-water sensor package that was designed for this system can handle up to 7 oceanographic sensors. Each are sequentially sampled. A hydrophone could also be included for continuous monitoring of the sound field. The depth of the instrument is obtained using an inverted echo sounder and a computer aboard the ship calculates from the measurements the depth of the instrument and the sound velocities to be associated with that depth The information was displayed on teletype output and on graphs and stored on digital magnetic tape. The results of that cruise have been analyzed and several reports have been completed. We believe this demonstrates a technical capability that the Geophysics Department has been striving for in this area of oceanographic measurements, namely, to provide reliable oceanographic measurements pertinent to acoustic transmission during and shortly following the completion of a cruise.

In summary, Contract Nonr-2866(00) was initiated as a project to provide basic environmental measurements in a broad ocean area between Bermuda and the Antilles that are related to the performance of a large long range underwater acoustic system known as Project ARTEMIS. From the beginning in 1958 until the present the research program included sound transmission studies and extensive studies of the ocean environment for acoustics. This program of research has brought about a better understanding of the ocean movements and reflecting properties of the ocean bottom in this large ocean area between Bermuda and the Antilles The basic nature of the findings in this area establish a base from which continued studies in this and adjoining areas can be fruitfully developed. Also during this contract period a reliable environmental ocean measuring system has been developed. This system is very useful in obtaining information about the spatial and temporal variations in the acoustic structure of the ocean.

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UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R&D

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1 ORIGINATING ACTIVITY *(Corporate author)*

WOODS HOLE OCEANOGRAPHIC INSTITUTION
Woods Hole, Massachusetts 02543

2a REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b GROUP

3 REPORT TITLE

FINAL REPORT OF CONTRACT Nonr-2866 INCLUDING A HISTORY OF THE CONTRACT AND A BIBLIOGRAPHY OF SCIENTIFIC CONTRIBUTIONS SUPPORTED BY THE CONTRACT AT THE WOODS HOLE OCEANOGRAPHIC INSTITUTION FROM MARCH 1, 1969 TO JUNE 30, 1969

4 DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Technical Report

5 AUTHOR(S) *(Last name, first name, initial)*

Beckerle, John C.

6 REPORT DATE	7a TOTAL NO OF PAGES	7b NO OF REFS
June 1969	18	94

8a CONTRACT OR GRANT NO	9a. ORIGINATOR'S REPORT NUMBER(S)
Nonr-2866; NR 287-004	WHOI Reference No. 69-51
b PROJECT NO.	
c.	9b OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d	

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	Office of Naval Research Washington, D.C.

13 ABSTRACT

The Contract was initiated as a project to provide basic environmental measurements in a broad ocean area between Bermuda and the Antilles that would limit the specifications and the performance of a large long range underwater acoustics system known as Project ARTEMIS. From the beginning in late 1958 until the present the research program included sound transmission studies, temperature and sound velocity measurements, studies of currents in the deep ocean and studies of the bottom conditions. This program of research has brought about better understanding of the ocean bottom in the Bermuda-Antilles area. A reliable environmental ocean measuring system was developed under this contract and put to use to determine spatial and temporal variations in the acoustic structure in the ocean.

DD FORM 1 JAN 64 1473

UNCLASSIFIED
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[14] KEY WORDS	LINK A		LINK B		LINK C	
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2. Final Report						
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